TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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A BALANCED DIAPHRAGM TYPE OF MAXIMUM CYLINDER PRESSURE INDICATOR

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Summary

A balanced diaphragm type of maximum cylinder pressure indicator was designed to give results consistent with engine operating conditions. The apparatus consists of a pressure element, a source of controlled high pressure, and a neon lamp circuit. The pressure element, which is very compact, permits location of the diaphragm within 1/8 inch of the combustion chamber walls without water cooling. The neon lamp circuit used for indicating contact between the diaphragm and support facilitates the use of the apparatus with multicylinder engines.

In measuring compression pressures only one reading is taken. However, in measuring maximum explosion pressures a range of pressure is read which shows the variation between individual cycles. This indicator is in current use at the Langley Memorial Aeronautical Laboratory as the most accurate available means for indicating maximum cylinder pressures.

Introduction

The problem of accurately measuring the maximum cylinder pressures in high-speed internal combustion engines is of considerable importance in their design, development, and operation. Efforts towards the solution of this problem have resulted in the development of a number of instruments, some of which are adaptations of those used for measuring pressures on slow-speed steam engines, while others are designed primarily for high-speed work (References 1, 2 and 3).

The indicator under discussion is similar in principle to the one described in N.A.C.A. Technical Report No. 107 (Reference 2). It has been used only for the measurement of maximum cylinder pressures, although it would be possible to build up a card by the point-to-point method described in Reference 2. The indicator as designed and used at the Langley Memorial Aeronautical Laboratory fulfills a specific set of conditions of operation, but can be applied to most engine test work.

Design

This maximum cylinder pressure indicator was designed particularly for use with experimental, high-speed, compression-ignition engines. The requirements were that it must withstand the high pressures involved in this work and give accurate readings of these pressures. The indicator must also be easy to service and be adaptable to several engines.

It was decided to use the principle of balancing pressures on either side of a diaphragm of negligible stiffness, because of the small mass of the moving element and the short distance of travel for making and breaking the contact. The most serious argument against the use of the diaphragm was the consideration of heat dissipation when located near the combustion chamber wall. Previous experience had shown, however, that a small diameter diaphragm remained sufficiently cool to prevent rupture and it was thought that any heat effect should increase the sensitivity of the diaphragm. Therefore, it was decided to operate the diaphragm without cooling (Figure 1).

Since the pressure element screws into a metric spark plug hole, the diameter of the diaphragm is limited to 1/2 inch and is clamped down to 3/8 inch free diameter. The diaphragm is made of Swedish blue tempered spring steel, which is sufficiently satisfactory, so that no other material has been tried. The diaphragm used is as thin as the particular pressures to be measured will permit, for in research work it is better to have an occasional failure than to sacrifice sensitivity by using a thick diaphragm. The thickness of the diaphragm for use with pressures up to 800 pounds per square inch has been 0.004 of an inch. A diaphragm 0.008 of an inch thick has been used with pressures up to 1500 pounds per square inch.

The diaphragm is mounted in the pressure element (Figure 2) between supports which allow it approximately 0.005 of an inch movement at its center and restrain it so that it is never distorted beyond the elastic limit. The outer support is dished to allow this movement. The inner support is less than 0.0005 of an inch from, but not in contact with the diaphragm in its normal position.

Using Morley's formula for deflection of a clamped diaphragm (Reference 4) a pressure of less than 4 pounds per square inch will cause the 0.004-inch thick diaphragm to make contact from its extreme position. This introduces an error of less than one per cent over its normal working range. The 0.008-inch diaphragm would be about 2 per cent in error at 1500 pounds per square inch.

The balancing pressure is provided from an air bottle connected to the pressure element through a control block on which a Bourdon spring gauge is mounted (Figure 1). A small neon lamp is mounted directly above the gauge. The lamp is made for operation on 110-volt alternating current, but is supplied with about 170-volt direct current from a bridge across the engine dynamometer circuit. For a single-cylinder engine only one lamp is used; however, for multicylinder engines a bank of neon lamps are used, each one for an individual cylinder, and readings of maximum cylinder pressure are taken simultaneously.

Operation

In the assembly of the pressure element it is most important to have the proper clearance between the diaphragm and the inner support. With this clearance of less than 0.0005 of an inch and the correct thickness of diaphragm, contact between the diaphragm and the inner support will be effected by a pressure within the error of commercial Bourdon spring gauges suitable for measuring the pressure.

In measuring compression pressures during motoring runs, the variation in pressure of individual cycles is so slight that only one pressure reading need be taken. This reading is taken by raising the controlled air pressure and reading the gauge at the point where the neon lamp stops flickering and goes out. The more slowly the pressure is raised the more accurate the reading will be. However, when running under power there is usually a variation in the maximum pressures of different cycles, so that the maximum cylinder pressures are read as a pressure range rather than as a single pressure. This is done by raising the pressure until the flickering of the lamp loses its regularity and taking one reading. The second reading is taken by increasing the pressure until the lamp ceases flickering entirely.

The troubles experienced with this instrument are diaphragm failures and short circuits. The diaphragm failures are usually due to fatigue or the employment of a diaphragm too thin to withstand the pressures with which it is used. The small amount of current necessary for lighting the neon lamp makes it possible for a small particle of foreign matter to cause the lamp to burn continuously if the parts are not clean at assembly. When motoring for long periods the accumulation of oil may have a damping effect on the diaphragm and cause the readings to be low.

No attempt has been made to definitely establish the accuracy of this instrument. However, it has been used simultaneously with the trapped-pressure type of valve (Reference 3) and, for compression pressures and combustion pressures with low rates of pressure rise, the two types give the same reading, but for high rates of pressure rise, the balanced diaphragm type indicates higher pressures. It has also been checked against the maximum pressures indicated by the altered "Farnboro" indicator (Reference 5) and found to be in close agreement.

This indicator shows almost instantly the effect on the maximum cylinder pressures of any variation in engine operating conditions. In the work at this laboratory the instrument has been found to give more consistent results than any other type available for the measurement of maximum cylinder pressures.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., November 17, 1930.

References

1. Judge, A. W. : The Testing of High-Speed Combustion Engines - 1925.
2. Dickinson, H. C., and Newell, F. B. : A High-Speed Engine Pressure Indicator of the Balanced Diaphragm Type. N.A.C.A. Technical Report No. 107, 1921.
3. Hicks, C. W. : The Measurement of Maximum Cylinder Pressures. N.A.C.A. Technical Report No. 294, 1928.
4. Morley, Arthur : Strength of Materials - 1926.
5. Collins, J. H. Jr. : Alterations and Tests of the "Farnboro" Engine Indicator. N.A.C.A. Technical Note No. 348, 1930.

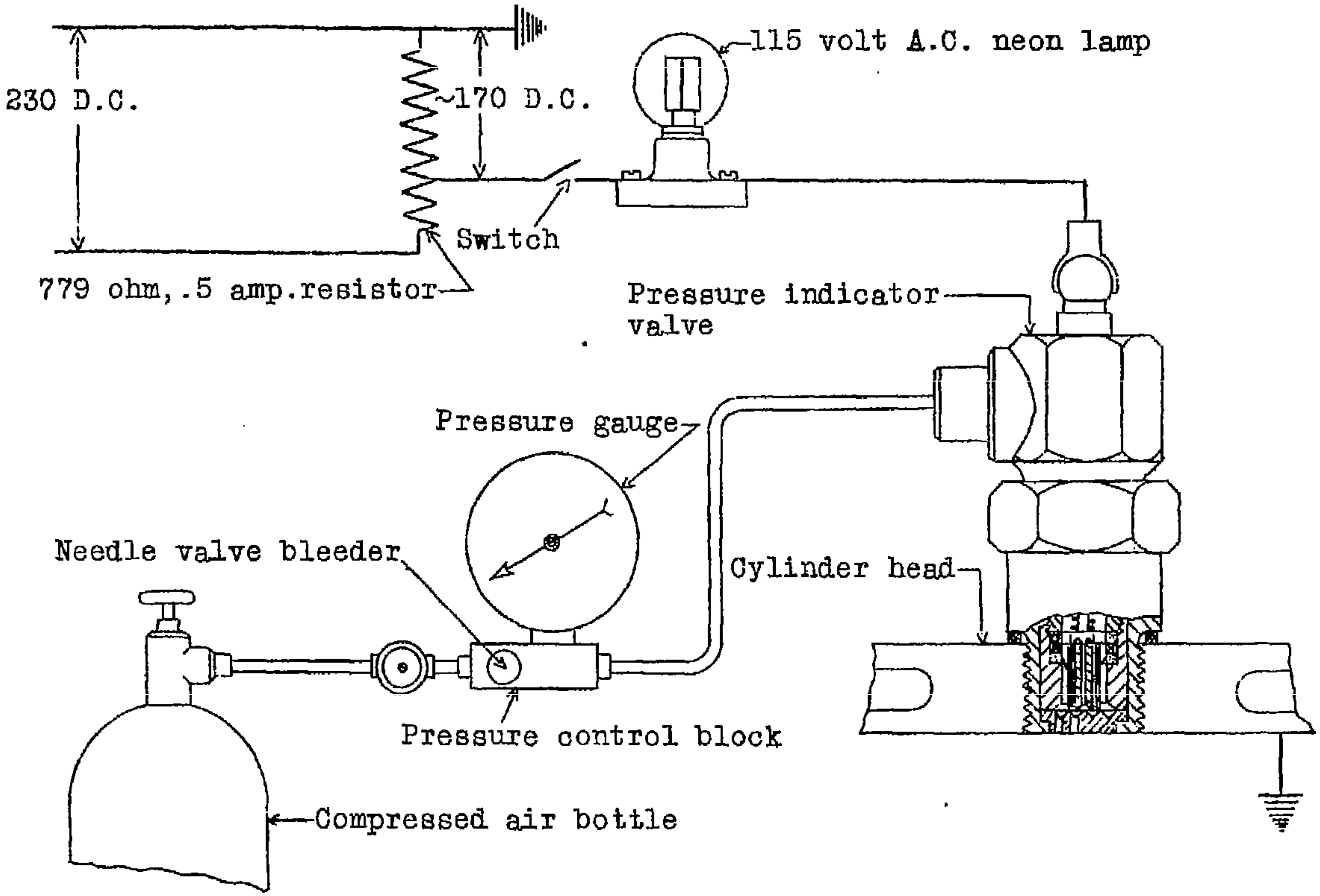

Fig.1 Diagrammatic sketch of pressure element and auxiliary apparatus.

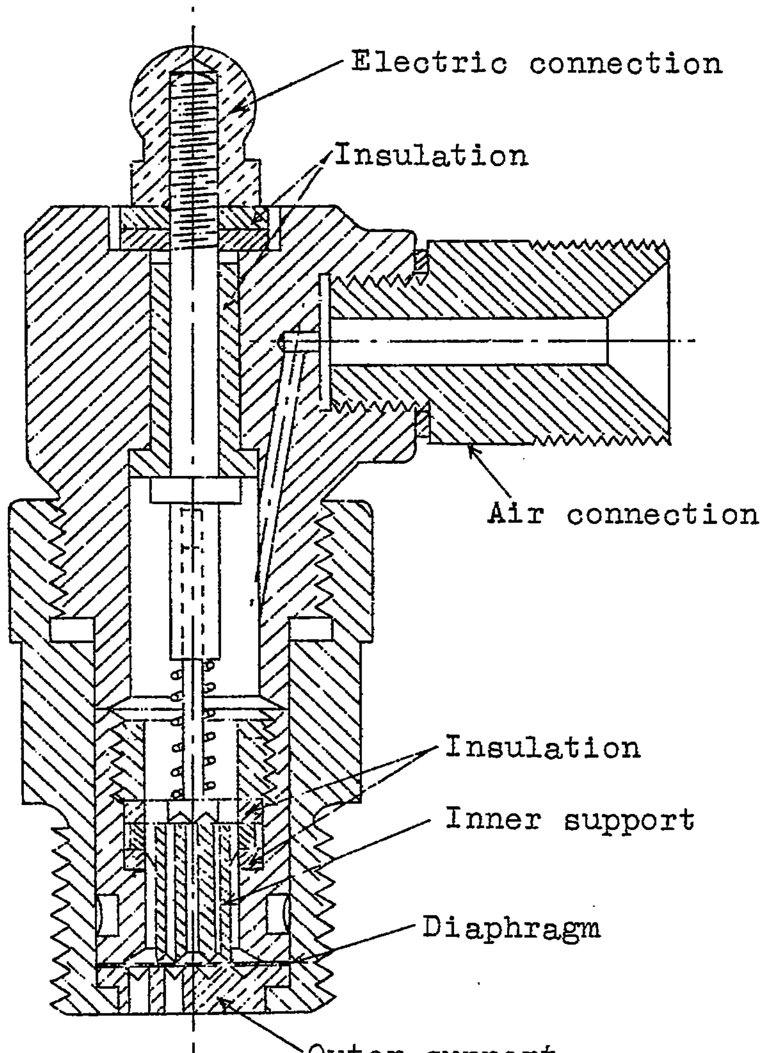

Fig.2 Pressure element N.A.C.A. diaphragm type maximum pressure indicator.

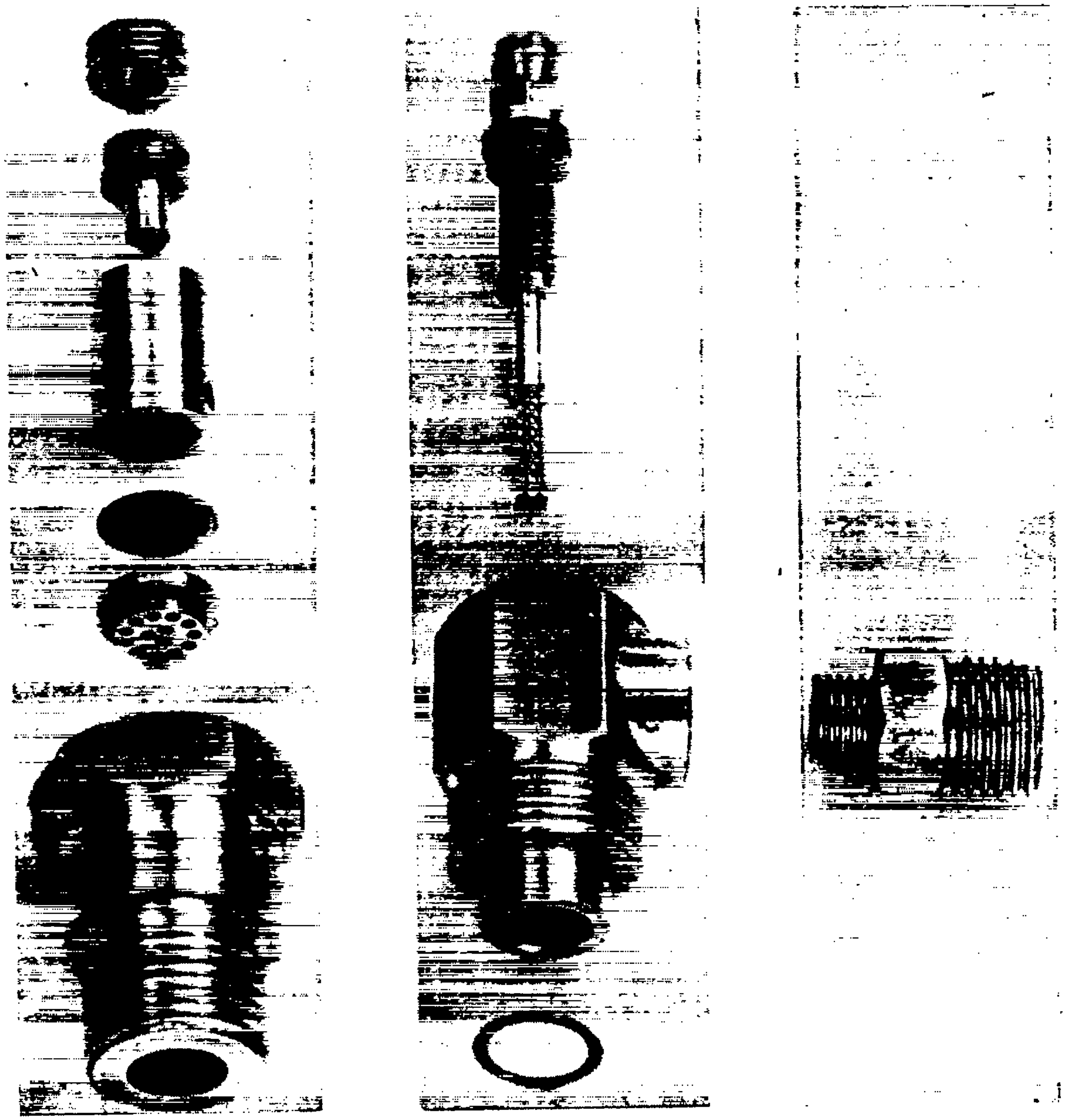

Fig. 3
Pressure element. Parts extended in order of assembly